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ABSTRACT

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In the paper, excitation and development of vibrations of gaseous mixture combustion in tubes are considered from the resonance point of view. The theoretical analysis of the problem is the interaction between self-induced vibrations and vibrations due to hydrodynamic instability of the flame front. The possibility of resonant excitation of the system depends on the waves of a definite length (2) present in the system. The experimental data confirm fairly well the adopted point of view (fig. 2).

Let us consider a flame front extending in a channel (cylindrical pipe) filled with a fuel gas mixture. In this case, as the theoretical and experimental investigations (refs. 2-4) indicate, the flame will be considerably distorted and assume the form shown in figure 1. Consequently, it can be taken locally for an inclined (at angle α) plane rupture surface HH which separates the initial mixture at a v_1 rate from the combustion products rate of v_2 . Introducing a mobile frame of reference which is moving along the inclined flame front HH, at a rate of $v_{1\tau} = v_{2\tau} = v_1 \cos \alpha$, we arrive at a scheme of a normal combustion front which converts the fuel mixture of the v_{1n} rate to

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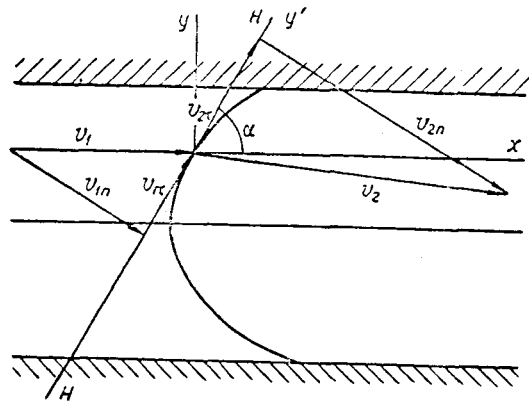


Figure 1. Ideal pattern of the flame front extension.

combustion products of the v_{2n} rate. After that we can use Landau's investigation (ref. 5) into the hydrodynamic instability of slow combustion in a linear approximation, according to which a small perturbation with a λ wavelength accidentally appearing on the flame front develops with time (assuming a fixed reference system), according to the following law

$$\xi = \text{const} \exp \left\{ i \frac{2\pi}{\lambda} (y' - v_1 t) - \Omega t \right\}, \quad (1)$$

and the negative value of the actual Ω magnitude accounts for the instability of a given traveling wave. This provides an explanation of the initiation and development of the vibration conditions accompanying the combustion of a gas mixture in a pipe from a resonance point of view. Actually, a small random perturbation on the flame front, which may always be assumed, generates, according to (1), a vibration process of the system at a frequency of $\frac{2\pi}{\lambda} v_{1\tau}$ and an amplitude rising with time and a logarithmic build-up factor Ω . This is, of course, accompanied by the excitation of the inherent gas column harmonics, cold mixture-combustion products, and the rapid establishment of a standing acoustic wave. The ^tinteraction between the natural acoustic vibrations of the

medium and the vibrations produced by the hydrodynamic instability of the system will reveal the resonance characteristics when the natural frequencies $2\pi\omega_n$ and the unstable frequency $\frac{2\pi}{\lambda} v_{1\tau}$ coincide or are close. That means that the possibility of a resonant excitation of the system depends on the presence on the flame front of definite wavelengths λ_r , which make the following possible

$$\omega_n = v_{2r}/\lambda_r = v_1 \cos \alpha / \lambda_r. \quad (2)$$

It may be expected that in most cases the latter will be found to be possible, albeit approximately, as it is actually a combination of various wavelengths, rather than a monochromatic wave, that takes place on the combustion surface. Because of the interaction between the acoustic vibrations of the gas column in the pipe and the vibrations of the flame front, the wavelength corresponding to the resonant excitation should rapidly grow in intensity. The damping forces which, in any event, always exist will facilitate the attenuation of the remaining wave formation and limit to some extent the intensification of the resonant waves (2). It is this process that, in our opinion, generates the combustion vibration conditions. The above considerations justify the conclusion that the wavelength on the flame front is connected with the acoustic vibration frequency of the gas column, and that the wavelength designed to meet the resonance requirement (2) will be generated primarily on the combustion front. Bearing in mind that ω_n and λ_r are determined by the characteristic dimensions of the vessel in which combustion takes place, we may expect to see a definite connection between the cylindrical pipe parameters, the disruption of which should result in the disruption of the resonance condition (2). In addition, a further distortion of the flame front, that is a further incline toward the stream, should, according to (2), be followed by an increasing wavelength on

the combustion front, and with $\alpha = \pi/2$, the frequency of the acoustic vibration should be reduced to zero.

We will now compare the conclusions with the experiment results cited in figure 2 to see if they correspond to the actual situation. The behavior of the flame front was studied during the combustion of homogeneous gaseous mixtures in cylindrical channels that are open at one end. The processes were recorded by a high-speed motion picture camera, and the optical nonhomogeneities were visually observed by the Schlieren method.

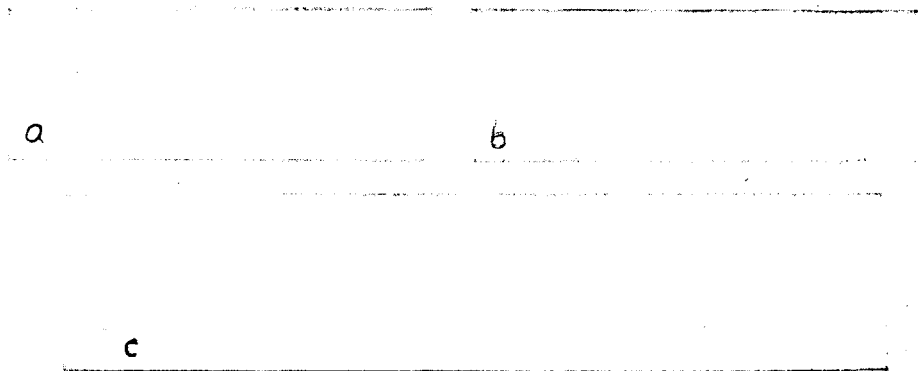


Figure 2. Instantaneous photos of a flame front in a rich air mixture of average purification (carbon-oxide air mixture). a - length of pipe 0.3 meter, cross section $28 \times 12.6 \text{ mm}^2$; b - 1.4 meter, cross section $28 \times 12.6 \text{ mm}^2$; c - 1.1 meter, cross section $34 \times 72 \text{ mm}^2$.

Cited in the table below is a comparison between the calculated wavelengths on the flame front and the experimentally obtained values. The flame spread under atmospheric pressure in an air mixture of average purification (excessive air factor 0.53) contained in a channel with a cross section of $28 \times 12.6 \text{ mm}^2$.

THE WAVELENGTHS ON THE FLAME FRONT

ω , hertz	0	75	130	530
λ_r theoret., cm	∞	0.85	0.42	0.24
λ_r experim., cm	∞	2.6	1.5	0.8
$\frac{\lambda_r \text{ experim}}{\lambda_r \text{ theoret}}$		3.1	3.5	3.3

It is clear that the computed values are smaller than the experimental ones. Nor could similar results be expected, inasmuch as average rates were used in the calculations. Curiously, the ratio of the above cited wavelengths is almost the same. This shows that the found pattern well corresponds to the existing one.

If the wavelength on the flame front in a meter channel with a $28 \times 12.6 \text{ mm}^2$ cross section is about 2 cm, it was found to be close to 3.7 cm in a similar channel with a $34 \times 72 \text{ mm}^2$ cross section; this shows that the wavelength is actually determined by the diameter of the pipe. Furthermore, the experiments revealed, in conformity with the conclusion, that the change of one of the parameters with the other remaining invariable may result in a cessation of the wave formation on the flame front. This is accompanied by the disappearance of the acoustic vibrations.

The interconnection between ω_n and λ_r was confirmed by the experiments carried out at low pressures. It was found that a decrease in the pressure increases the wavelength on the flame front and reduces the frequency of the acoustic vibrations at the same time.

Finally, when the pressure is relatively low ($P \approx 2 \cdot 10^4 \text{ n/m}^2$), the flame front assumes a symmetrical form, slightly convex on the side of the unburnt

mixture, in relation to the channel axis. In this case, the waves are absent /127 from the front surface; in other words, the wavelength becomes very large. As for the acoustic vibration frequency, it in the majority of cases equals zero, although a very definite vibration frequency of the gas column is occasionally observable. This experimental fact may conform to the theory if we assume that $a = \pi/2$ which is, generally speaking, close to reality. The possible reproduction of the results was checked by the CO, C₃H₈ and C₂H₂ combustion.

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26 March 1964

REFERENCES

1. Aslanov, S. K., Inzhenerⁿ_o-Fizicheskiy Zhurnal, No. 5, 1964.
2. de Ellis, O. C. and Kirby^k, W. A. Flame Methuen's Monographs on Chemical subjects. London, 1936.
3. Coward, H. F. and Hartwell, F. I. Journal of the Chem. Society, 1996, 2676, 11932.
4. Tsien, H. S. Journal of Applied Mechanics, 18, 188-194, 1951.
5. Landau, L. D. and Lifshits, Ye. M. The Mechanics of Continuous Media (Mekhanika sploshnykh sred). GITTL (State Publishing House for Technical-Theoretical Literature), 1953.